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Published by the Ontario Ministry of Agriculture and Food · Agricultural Energy Centre · 801 Bay Street · Toronto · M7A 2B2 · (416) 965-9519

AGDEX 261
717

WATER SOURCE HEAT PUMPS IN A MUSHROOM PLANT

FINAL REPORT

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APRIL 1987

ABSTRACT

Twenty-Five Tons of water-to-water heat pumps were installed to provide the heating and cooling for a modern mushroom plant. In the heating mode the heat pumps reduced the cost of heating by 56% on average, compared to natural gas produced steam.

WATER SOURCE HEAT PUMPS IN A MUSHROOM PLANT

BY

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INTRODUCTIONS

Optimum mushroom production requires precise year-round control of the growing environment. Various parameters such as; temperature, carbon dioxide levels, fresh air, and humidity levels have to be carefully varied according to the growth cycle of the mushroom.

In 1983 modifications were carried out on a mushroom plant which utilizes a Dutch Tunnel growing system. At that time water-to-water heat pumps coupled to a ground loop were added to supply cooling for this plant, which has six growth rooms, each with a bed area of $370m^2$. Prior to this time no mechanical cooling was available and a variety of mushrooms was grown, which was more heat tolerant.

HEAT PUMP SYSTEM

Water source heat pumps connected to a buried ground loop serve to provide total cooling as well as partial heating for this modern mushroom plant. The five heat pumps used were WaterFurnace Model No. WHP-541, 5 Ton water-to-water units.

NOTE: The mention of manufacturers' trade names is for the purpose of specific equipment description and does not indicate an endorsement of that equipment or discrimination of similar equipment by the author or Ontario Ministry of Agriculture and Food.

The ground loop for this system consists of 2400m of 38mm diameter polyethylene pipe buried 2300mm deep in a field adjacent to the mushroom plant. This loop was installed as a single pipe per trench, in eight individual equal length loops, each 300m long. Each individual loop was then connected to common supply and return headers inside the building. A large agricultural chain trencher was used to dig the trench for the ground loop. The soil type at this location is Napanee clay which is an imperfectly drained grey clay, underlain by a heavy clay subsoil. This ground loop was installed nearly 1000mm deeper than conventional residential ground loops. This deeper loop placement was done to insure that the loop would be in saturated soil, especially during the period of the new year when cooling is required. When heat is rejected to the ground loop during the cooling mode, water is driven away from the loop and possible baking of the soil around the loop pipe could occur. However, with deeper placement the soil should remain saturated year round thereby eliminating the possibility of the soil being dried out by the heat from the ground loop.

Cost for the polyethylene pipe and trenching was approximately $3.25 per metre of loop. Since high temperatures are required in the plant for compost cookout, which are not possible with heat pumps, steam from a natural gas fired boiler is still required.

In the heating mode, three heat pumps are used to supply heat to the plant. In the cooling mode, the total five heat pumps are utilized to extract heat from the plant and dissipate it through the ground loop to the soil. The heat pumps are staged to provide better control and reduce energy wasteage from overloading or underloading. Depending on the mode of operation either warmed or cooled water is moved from the heat pumps by a heat transfer loop through the plant. As required, controls in each growing room activate solenoid valves, which allow water to flow either through the heating or cooling air coil.

A brine or calcium chloride and water solution was used as the heat transfer fluid in the ground loop, when first installed. Persistant leaks and surface corrosion caused by the brine, necessitated a change to a glycol and water solution in the loop.

RESULTS

A digital readout thermometer and thermocouples were used to measure loop temperatures at various times. A kilowatt hour meter was used to measure electrical energy consumption by the heat pumps and loop pump. Natural gas consumption was measured by means of the gas billing meter located at the plant.

Tests were carried out whereby one or the other heat sources, namely heat pumps or steam boiler was used exclusively for heating for twenty-four hour test periods. The results of these heating tests are summarized in Table #1. From Table 1 the average heating cost reduction by using the heat pumps vs. the boiler for heating is $\frac{55.0 + 55.4 + 56.9}{3} = 55.8\%$

Therefore the heat pumps heat the building, on average, for approximately 56% less cost than heating with the natural gas fired boiler.

Figure #1 illustrates graphically the incoming loop temperature over time. These temperatures were monitored on a bi-weekly basis. It can be seen that through the heating season the incoming loop temperature starts at approximately 18°C and levels out near 2°C. In the cooling mode the loop temperature rises from approximately 3°C at the start of May and peaks in mid-September near 32°C. Ideally we would like to see the loop temperature remain somewhat cooler during the cooling season.

When the system was first installed the loop was sized to 15 Tons of heat pump capacity, thereby having a loop length of 160m per Ton of heat pump. Conventional ground loops are sized from 120m to 140m of length per Ton of heat pump. With 25 Tons of heat pump coupled to 2400m of ground loop, we have only 96m of loop per Ton of heat pump capacity. These heat pumps however will operate well with loop temperatures not exceeding 43°C.

During the months of January and February, due to cool loop temperatures, the heat pumps were unable to supply sufficient heat to the rooms to provide a quick temperature response desired. Because of this fact, the farmer elected to shut off the heat pumps and used his boiler to supply this heat. A heat exchanger could have been used to boost the heat transfer loop temperature with heat from the boiler to desired levels. In this manner the heat pumps could still be supplying a base load of heating.

PROBLEMS EXPERIENCED

1. The brine solution in the ground loop caused considerable surface corrosion at locations where small leaks are present. The change to a glycol and water solution eliminated this surface corrosion problem.
2. Due to the cold ground loop temperatures during January and February, the heat pumps were not able to warm the building heat transfer loop sufficiently to provide the quick response desired by the farmer. For these two months, steam from the boiler was used to maintain proper temperatures in the growing rooms.
3. Warm summer loop temperatures do not cause any problems as yet. However, if these temperatures approach 43°C, increasing the amount of loop should be considered.

CONCLUSIONS

This water-to-water heat pump system works well to provide total cooling as well as partial heating for this mushroom production facility. The fact that the heat pumps cannot provide high enough temperatures on the load side during January and February is an inadequacy of the system. However, since a boiler is required for compost cookout and is available, this boiler can be used to supply this heat during this two month period. The heat pumps have performed very well with few mechanical problems.

Payback calculations for this system are not possible since a plant expansion has taken place since the system was installed. As well, a totally different type of mushroom is now being grown which requires different growing conditions. The concept of water source heat pumps for cooling and heating a mushroom plant shows merit and should be considered for new or retrofit applications.

ACKNOWLEDGEMENTS

The author would like to thank the cooperator, Mr. Wiet Peeters for allowing this monitoring to be carried out at his mushroom facility. As well, thanks to Ontario Hydro for supplying the kilowatt hour meter to measure electrical energy consumption.

TABLE #1. HEAT COST COMPARISON

- TESTS were carried out back-to-back, each test being 24 hours in length. During these tests either heat pumps or the boiler were being used exclusively for heating the plant.
- 6 growth rooms being heated.
- ELECTRICITY PRICE $0.05/kWh
- NATURAL GAS PRICE $0.19/m^3

TEST NUMBER	AVERAGE AMBIENT	ELECTRICITY USED	COST	NATURAL GAS USED	COST	HEATING COST REDUCTION H.P. vs. BOILER
1A	- 2°C	205kWh	$10.25			$\frac{\$12.55}{\$22.80} \times 100 = 55.0\%$
1B	- 3			120m^3	$22.80	
2A	- 6°C	210KWh	$10.50			$\frac{\$13.06}{\$23.56} \times 100 = 55.4\%$
2B	- 5			124m^3	$23.56	
3A	-11°C	216kWh	$10.80			$\frac{\$14.28}{\$25.08} \times 100 = 56.9\%$
3B	-12°C			132	$25.08	

Average Heating Cost Reduction = $\frac{55.0 + 55.4 + 56.9}{3} = 55.8\%$

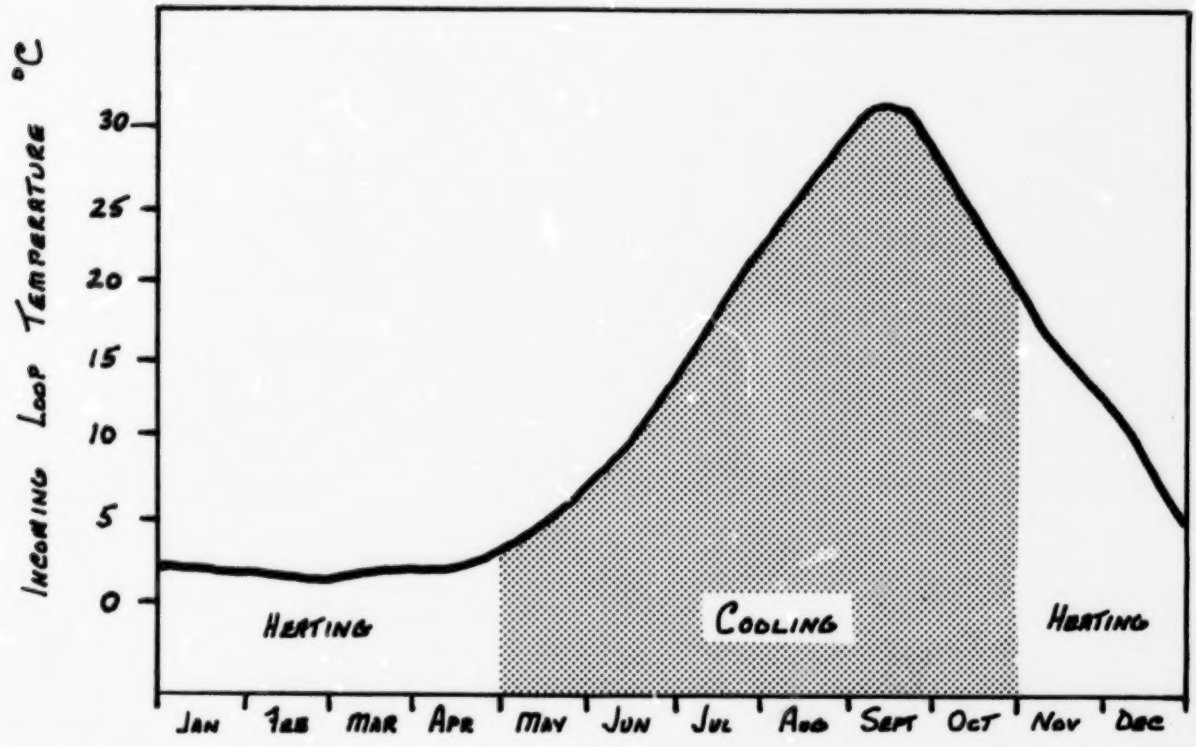

FIGURE I INCOMING LOOP TEMPERATURE VS. TIME